THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

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THE MOND NICKEL COMPANY LTD • THAMES HOUSE, MILLBANK, LONDON, S.W.1
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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

ELECTRODEPOSITION AND OTHER COATING METHODS

Porosity Testing of Electrodeposited Nickel Coatings

R. H. WOLFF, M. A. HENDERSON and S. L. EISLER: 'Porosity of Nickel Deposits by Autoradiographic Techniques.' *Plating*, 1955, vol. 42, May, pp. 537–44.

The authors describe a method involving plating of nickel over an electrodeposit of radioactive iron on steel. The nickel films are evaluated, for the presence of discontinuities, by the use of photographic film suitably exposed to radiation emanating from the iron through the nickel plating. Specimens prepared from five different nickel-plating solutions were used in these tests; the coatings were representative of those made from three types of bath: (1) the proprietary chemical-reduction or electroless method, (2) the conventional Watts bath, with and without proprietary brightening agents, and (3) the phosphorus-nickel bath developed by BRENNER, COUCH and WILLIAMS (*Jnl. Res. Nat. Bur. Standards*, 1950, vol. 44, p. 109). Autoradiographs typical of deposits from all five baths are shown in the report. At the conclusion of these tests all the plated coupons were subjected to a boil test in aerated water, using the procedure laid down in U.S. Military Specification MIL-C-12968. The results of these tests were photographically compared with the autoradiographic determinations.

A survey of the autoradiographs shows that the method is capable of revealing differences in the nickel plating, and the comparison of these results with those of the boil test indicate a general trend. With increasing thickness of coating the boil-test spots decrease in number, which is to be expected as gross porosity decreases. The autoradiographs show a general increase in number of spots as the thickness of the coating increases, suggesting the presence of pits and voids, as well as the gross pores. Evaluation of the data obtained indicates that the coatings produced for the tests may be rated, *in order of increasing porosity*, as follows:—

Proprietary electroless process
Electroless process as developed by Brenner
Proprietary bright nickel plating
Low-pH phosphorus-nickel
Watts nickel (unpurified and unfiltered)

The conclusion is reached that the radioactive method offers considerable promise, in that it is sensitive in evaluation, non-destructive, reproducible, produces a permanent record, is not limited to use on nickel plating but may be used on other electrodeposited coatings, and could be used in the study of long-term corrosion tests (by means of periodic autoradiographs). Two further advantages are that the equipment required is easily available commercially and that, although radioisotopes are used, the radiation level is so low that there is no hazard to personnel, provided that normal precautions are ensured.

NON-FERROUS ALLOYS

Monel Stays in Locomotives for the Sudan

'Oil-fired Locomotives for the Sudan Railways.' *Railway Gazette*, 1955, vol. 103, July 22, pp. 103-4.

A description is given (with dimensioned drawing) of the design of locomotives which are now under construction by the North British Locomotive Company, Ltd., for the Sudan railways. The engines, which are of the 4–8–2 type with four-wheel double-bogie tenders, are for 3-ft. 6-in. gauge and are equipped with oil-burning apparatus. Forty-two units are to be supplied.

In considering the features of boiler design, it is noted that the inner firebox is of copper and is stayed to the roof of the round-top outer firebox by direct Monel stays. Water-space stays, also of Monel, are fitted at the sides, back and combustion chamber of the firebox.

Monel-Clad Steel in Marine Protection

See abstract on p. 167.

Corrosion-Resisting Alloys for Chlorine-Dioxide Pulp Bleaching

See abstract on p. 166.

Amalgams as an Aid in the Study of Nickel-Alloy Systems

F. LIHL: 'Amalgams as an Aid in Metallurgical Research.' *Zeitsch. f. Metallkunde*, 1955, vol. 46, June, pp. 434–41.

Difficulties arising in the study of equilibrium diagrams in alloys prepared by melting or by sintering are briefly reviewed, and the advantages to be gained by preparation at relatively low temperatures, by reduction or by amalgamation, are urged. The process of amalgamation is described in detail, with comments on its advantages and limitations. Results obtained on nickel-zinc, nickel-tin, cadmium-nickel, nickel-iron, cobalt-nickel and other alloys so prepared are referred to in demonstration of the value of the technique recommended.

Magnetic Structure of Nickel-Iron and Nickel-Manganese Alloys

See abstract in Nickel-Iron section.

Influence of Nitrides and Addition Elements on Elastic Modulus of Aluminium Alloys

N. DUDZINSKI: 'The Effect of Nitrides and Ternary Intermetallic Compounds on the Young's Modulus of Some Aluminium Alloys.'
Jnl. Inst. Metals, 1954-55, vol. 83. June, pp. 444-8; Advance Copy 1618.

Earlier investigations on the mechanical properties of some aluminium alloys had shown that the elastic modulus was improved by the addition of certain elements and that the effect was proportional to the amount of the added element. It was believed that in some of the alloys the presence of intermetallic compounds was responsible for the rise in the modulus, and the suggestion was made that the most effective compounds would be those having a high heat of formation.

The tests now reported were made on various binary and ternary aluminium-base alloys prepared by chill casting or by sintering and extrusion. It was found that the presence of nitrides of aluminium, chromium, magnesium, iron, vanadium, and titanium caused an appreciable increase in Young's modulus. Ternary intermetallic compounds showed a similar effect, e.g., a substantial gain was observed in aluminium-iron-nickel alloys.

Modulus values of aluminium-iron-nickel alloys proved especially interesting, on account of the formation of a ternary compound which, according to Mondolfo, is monoclinic, isomorphic with Co_2Al_9, and has the composition $FeNiAl_9$. This compound contains a larger number of aluminium atoms than either $FeAl_3$ or $NiAl_3$, and the two metals in combination were therefore expected to be more effective than separately. This expectation was confirmed by results shown in the paper, which indicate, *inter alia*, that an alloy containing nickel 4·17 and iron 2·32, per cent. has a Young's modulus 13 per cent. higher than that calculated by adding the known effects of nickel and iron when present separately.

The detrimental effect of magnesium was offset by additions of chromium or manganese, resulting in an improvement in the modulus. The relationship of the modulus to the composition and heat of formation of various intermetallic compounds is discussed.

Influence of Nickel on Germanium

W. W. TYLER, R. NEWMAN and H. H. WOODBURY: 'Properties of Germanium Doped with Nickel.' *Physical Rev.*, 1955, vol. 98, Apr. 15, pp. 461-5.

The paper presents results of measurements of electrical and optical properties on germanium crystals containing nickel as a major impurity. In work primarily concerned with the effects of nickel and copper on carrier lifetime in germanium, BURTON *et al.* had reported data on low-temperature conductivity and Hall coefficient, indicating that nickel introduces an acceptor level at about 0·23 ev. from the valence band of germanium (*Jnl. Phys. Chem.*, 1953, vol. 57, p. 853). This conclusion was confirmed by the present authors, and in addition, they give evidence of the introduction, by nickel, of another acceptor level, at about 0·30 ev. from the conduction band. The distribution coefficient for nickel in germanium is about $2·3+10^{-6}$. A summary is made of the properties of iron-, cobalt- and nickel-doped germanium crystals.

Sintering of Mixed Metal Powders

K. HIJIKATA: 'On the Sintering of Mixed Metal Powders of Various Kinds. I. Mixed Powders of Copper and Nickel. II. Mixed Powders of Iron and Nickel.' *Nippon Kinzoku Gakkai-Si*, 1954, vol. 18, pp. 244-7; 247-50.

I. Powder mixtures containing 57:43 weight per cent. of copper and nickel, of varying particle sizes, were pressed at 30 and at 100 kg./mm², and homogeneity during subsequent heat-treatment was studied by metallographic and X-ray diffraction methods and by measurements of the temperature coefficient of electrical resistance.

II. The influence, on homogeneity, of various methods of mixing iron and nickel powders was studied by measurement of thermal expansion of sintered and of forged compacts containing about 36 per cent. of nickel.

The main conclusions drawn from each series of experiments are summarized in *Metallurgical Abstracts*, 1955, vol. 22, June, pp. 957-8.

NICKEL-IRON ALLOYS

Magnetic Structure of Nickel-Iron and Nickel-Manganese Alloys

C. G. SHULL and M. K. WILKINSON: 'Neutron Diffraction Studies of the Magnetic Structure of Alloys of Transition Elements.' *Physical Rev.*, 1955, vol. 97, Jan. 15, pp.304-10.

As a contribution to the study of magnetic structure, neutron diffraction data are presented for a series of alloys of transition elements.

Ferromagnetic disorder scattering was found for alloys in the disordered state and magnetic superstructure scattering was observed for ordered alloys. Magnetic scattering data, when combined with observations on magnetization, provide information on the individual atomic magnetic moments present in the alloys. In general, the atomic magnetic moments deviate from their pure elemental values as a function of alloy composition. Information on scattering and on magnetic moment is given for selected alloys in the iron-chromium, nickel-iron, cobalt-chromium and nickel-manganese series.

Sintering of Mixed Metal Powders

See abstract above.

CAST IRON

Alloy Cast Iron for Tappets

H. CHASE: 'Special Hardenable Iron Developed for Tappets.' *Automotive Industries*, 1955, vol. 112, May 1, pp. 52–55.

Chilled cast iron and carburized steel have been used with fair success for hydraulic valve tappet bodies, but such materials are not entirely satisfactory, being subject to failure as a result of scuffing (metal pick-up), fatigue, or corrosion, or by a combination of all three factors. Scuffing and fatigue are attributed mainly to the high loading which occurs, especially at high speed, in engines in which heavy spring pressure is employed. Corrosion is in some cases enhanced by additives used in certain oils called for by extreme-pressure conditions. Typical failures are illustrated in this article.

Following considerable research and extensive tests, Chrysler Corporation has developed an improved tappet iron, which, by comparison with other materials, shows outstanding resistance to the effects leading to premature failure. Accelerated laboratory tests, while not strictly comparable in all respects with service conditions, have indicated conclusively that this hardenable cast iron, of the composition shown in the table below, will long outlast tappets made from other types of cast iron, hard-facing materials, and low- or high-alloy steels. All the tests reported were made against Chrysler standard cast camshafts, which, in the as-cast condition, have a hardness of 269–302 Brinell and are flame-hardened to Rc 50 minimum.

Hardenable Alloy Iron for Tappets

	%
Total Carbon	3·10–3·30
Combined Carbon	1·00–1·20
Silicon	2·10–2·30
Manganese	0·70–0·90
Phosphorus	0·20 max.
Sulphur	0·10 max.
Chromium	1·00–1·25
Molybdenum	0·50–0·70
Nickel	0·40–0·70

In addition to compositional specifications, it is laid down that the iron must be made in the electric furnace, according to best current practice, and requirements for hardness and microstructure of the hardened alloy cast iron are specified. Typical photomicrographs prepared for use as standards for checking of microstructure before and after hardening are shown in this article. The tappets are machined in the as-cast condition and, after machining, are heated to 1550°–1600°F. (840°–870°C.), quenched in oil, and tempered for two hours at 350°F. (175°C.), to give the required hardness of Rc 55 min. Heat-treatment is followed by finish-grinding, and by application of a Lubrite finish to the tappet face, which is required to have a 20 micro-inch smoothness.

Thermal-Shock Resistance of Cast Irons

E. R. EVANS: 'Thermal Shock. Some Experiments with Cast Iron.'
Brit. Cast Iron Research Assocn., Jnl. of Research and Development, 1955, vol. 5, June, pp. 643–54; *Research Rept. No.* 407.

Defects resulting from thermal shock may be classified into three groups:—

(1) surface cracking or crazing, which may occur at any position in the casting ('minor cracking');
(2) cracking causing separation of parts of a casting, frequently caused by design factors ('major cracking');
(3) growth and warping essentially due to the time for which a component is kept at high temperatures, but which may be accelerated by repeated cooling.

The author reviews relevant literature and describes in detail an investigation on thermal shock as a cause of major cracking.

The first part of the report deals with development of apparatus for thermal-shock testing. Various designs of test piece were investigated, and apparatus for automatic and repeated heating and cooling of specimens was constructed. Full details of the experimental technique are given, with illustrations.

The temperatures, number of cycles of heating and cooling, and other test conditions were varied, the influence of carbon, silicon and other elements was studied in plain irons, and tests were made on two cerium-treated and two nickel-magnesium-treated spheroidal-graphite irons and an ingot-mould iron. Typical examples are reported to indicate the behaviour of the respective groups.

It is concluded that while major cracking can be caused in cast-iron components by thermal shock, propagation of the cracks is governed by the design of the component: cracking may occur in re-entrant angles or at abrupt changes in section. Laboratory test pieces of cylindrical form, having a pattern of holes, are specially suitable for determination of thermal-shock resistance of cast iron. Using such test pieces as a means of studying the influence of composition, etc., on behaviour under alternate heating and cooling, the following facts were established.

Resistance to thermal shock is markedly lessened when the phosphorus content of cast iron is raised from 0·05 to 1·4, per cent. Increase in carbon from 2·99 to 3·66, per cent. had a slightly deleterious effect. Resistance to thermal shock is improved as the silicon content is increased from 1·3 to 3·0, per cent.

Ingot-mould irons show better resistance than grey cast irons of finer graphite structure.

Of all the irons tested, spheroidal-graphite irons show the best resistance to thermal shock.

Low-Expansion Austenitic Nickel-Alloy Cast Iron

H. BROWN: 'Low-Expansion Cast Iron.' *Machine Design*, 1955, vol. 27, June, p. 175–7.

The increasing use of precision equipment in which

very close dimensional tolerances are significant has focused much interest on materials of construction which, in addition to other attractive mechanical and physical properties, are characterized by controllable expansion. This article describes one such material, an alloy cast iron containing 36 per cent. of nickel, which has already found much use in parts of precision machine tools, scientific instruments, gauges, measuring devices, etc.

The linear coefficient of expansion of this material ($2{\cdot}2\times10^{-6}$) is about one-third that of ordinary grey cast iron, and the alloy iron has the further advantages of gall-resistance, good damping capacity, machinability and corrosion-resistance. Properties typical of the material, which is known as 'Minovar', are shown in the table below:

Mean Coefficient of Expansion*		
	in./in./°F.	
	50°–125°F.	$2{\cdot}18\times10^{-6}$
	50°–200°F.	$2{\cdot}24\times10^{-6}$
	50°–300°F.	$2{\cdot}40\times10^{-6}$
	50°–400°F.	$2{\cdot}75\times10^{-6}$
Strength	*p.s.i.*	*t.s.i.*
Tensile	20,000– 25,000	9 –11
Compressive	80,000–100,000	35·5–44·5
Torsional	30,000– 35,000	13·5–15·5
Transverse properties		
A.S.T.M. type B bar		
Load, *lb.*		1,800–2,000
Deflection, *in.*		0·6–0·9
Modulus of elasticity, *million p.s.i.*		
Tensile (at 25 per cent. of tensile strength)		10·5
Torsional		4·5
Endurance limit, *p.s.i.*		9,900
Hardness, Brinell		100–125
Impact Strength, *ft.–lb.*†		150
Pattern shrinkage, *in. per ft.*		$\frac{3}{16}$
Specific gravity		7·6
Density, *lb. per cu. in.*		0·275
Melting point, *°F.*		2250
Thermal conductivity, *cal./cc./sec./°C.*		0·094
Electrical resistivity, *microhm per cc.*		160–170
Magnetic response, % of grey iron		about 70

Since Minovar castings are used primarily in applications in which dimensional stability is imperative, annealing, to remove strains resulting from casting and rough machining, is desirable. The treatment recommended for production of optimum stability is annealing at 1100°–1200°F. (595°–650°C.) for one hour per inch of thickness, followed by cooling in the furnace.

* Alloy cast iron containing 35 per cent. nickel.
† Unnotched arbitration bar struck 3 inches above supports.

Oxidation-Resistance of Nickel-Alloy Cast Irons

R. J. GREENE and F. G. SEFING: 'Cast Irons in High-Temperature Service.' *Corrosion*, 1955, vol. 11, July, pp. 315t–21t.

Suitability of cast irons for high-temperature applications has hitherto been gauged mainly on resistance to growth, and laboratory and large-scale tests have demonstrated the combined influence of volume change, localized cracking, and oxidation, as contributory to growth. Growth tests on cast irons and steels have not, however, shown entirely satisfactory correlation with service experience, and it has been found desirable to investigate more closely the rôle of oxidation in determining high-temperature serviceability.

In this paper the authors report results of oxidation tests on plain and alloyed cast irons (both low- and high-nickel types) and stainless steel, exposed for varying periods and under various conditions. Typical conditions for which tabulated data are presented include results obtained after exposure:—

(*a*) for 2,000 hours at 1400°F. (760°C.) in an electric-furnace air atmosphere (17–19% oxygen);

(*b*) for 3,723 hours at 1375°–1400°F. (746°–760°C.) in an electric-furnace air atmosphere;

(*c*) for 1,677 hours at 1500°–1700°F. (815°–926°C.).

Comparison of the growth- and oxidation-resistance data in the various tests confirm the significance of oxidation behaviour as a criterion of high-temperature serviceability. Growth tests measure dimensional changes which are influenced by the graphitizing potential of the material and by the type of decomposition product formed at the elevated temperatures. These factors limit the practical usefulness of growth tests, since the data so obtained do not necessarily reflect the rate of deterioration of the metal in service. Oxidation tests, however, discriminate clearly between the heat-resisting properties of the various grades of cast iron.

Evidence is shown that alloy additions in grey cast iron have a stabilizing effect, reduce growth, and improve oxidation-resistance. In general, the improvement in growth- and oxidation-resistance is proportional to the amount and nature of the alloy elements added, especially nickel, chromium and silicon.

Unalloyed cast irons are usually limited in useful service to temperatures below 900°F. (480°C.). Low alloy irons may be used up to about 1100°F. (600°C.), and highly alloyed irons, such as Ni-Resist, will give economical service up to 1200°F. (650°C.) or above. In addition to their growth- and oxidation-resistance, the highly alloyed irons have the advantage, over plain and low-alloy types, that they have appreciable load-carrying capacity at high temperatures.

Ni-Resist cast irons containing nickel of the order of 14–30 per cent. have been used for a considerable time in high-temperature applications, such as rollers, skid bars, and other furnace parts, at temperatures up to about 1500°F. (815°C.), and with the advent of ductile Ni-Resist (the magnesium-treated counterpart of Ni-Resist), the elevated-temperature applications of these high-alloy irons should be considerably expanded. Two other groups of alloy irons which show good resistance to heat are those containing 15–25 per cent. of chromium and the 5–6 per cent. silicon cast irons. Both types suffer, however, from the serious disadvantage of excessive hardness and brittleness, and their service use must therefore be

restricted to applications where but little machining is necessary and in which temperature fluctuations are so slight as to obviate thermal shock.

HEAT- AND CORROSION-RESISTING MATERIALS

Nimonic Alloys: Recent Developments: Nimonic 100

'Further Developments in the Nimonic Alloys: Nimonic 100.' *Aeroplane*, 1955, vol. 89, Aug. 26, p. 294; *Engineer*, 1955, vol. 200, Aug. 26, p. 305; *Aircraft Production*, 1955, vol. 17, Oct., p. 413.

Preliminary information has been issued by Henry Wiggin and Company, Ltd., with regard to a new alloy in the Nimonic series, designated Nimonic 100. Like previous alloys of this group, it has been developed in the laboratories of The Mond Nickel Company, Ltd. The new alloy, now under test by several gas-turbine builders, is, like its predecessors, characterized by very high resistance to creep, and it has the advantage that it can be used at temperatures some 30°C. higher than those which are permissible for any alloy previously available in this series. The properties quoted below are given as a basis of design.

Stress-to-Rupture Properties of Nimonic 100

Temperature °C.	Stress (tons per sq. in.) for rupture in		
	50 hours	100 hours	300 hours
870	13·5	12·0	9·5
925	8·5	7·0	5·5
940	6·7	6·0	4·5
980	4·0	3·5	3·0

Progress which has been made during recent years is well exemplified by the following comparison of temperature for fracture under specified conditions for four alloys of the Nimonic series:

Alloy	Temperature for Fracture in 100 hours at 5 tons per sq. in. °C.
Nimonic 80A	870
,, 90	900
,, 95	925
,, 100	950

A revised handbook giving the latest information available, on the whole series of the Nimonic alloys, has recently been published by Messrs. HENRY WIGGIN AND COMPANY, LTD., under the title 'The Nimonic Alloys: Design Data', *Publn.* 943,* 48 pp.

* *We shall be pleased to supply a free copy of this publication.*

Rare-Earth Additions to Cobalt-Chromium-Nickel-base Alloy

J. E. BREEN and J. R. LANE: 'Effect of Rare-Earth Additions on the High-Temperature Properties of a Cobalt-base Alloy.'
Amer. Soc. Testing Materials, Preprint 94c, June, 1955; 9 pp.

Rare earth additions have been shown to be beneficial in stainless and low-alloy steels and in spheroidal-graphite cast iron, and such modification has been found also to improve the high-temperature properties of aluminium and magnesium. The present paper reports experiments made to ascertain the influence of rare-earth elements in a cast high-temperature alloy containing cobalt 55·6, chromium 25·5, nickel 10·4, tungsten 7·1, carbon 0·37, per cent., with small amounts of other elements. Most of the castings examined were prepared by the lost-wax method, but the tests also included specimens machined from 15-lb. ingots and specimens forged from these ingots. The rare-earth additions were made in amounts of 0·5 and 2·0, per cent.

The criteria used were properties obtained in stress-rupture tests at 1500°, 1600° and 1700°F. (815°, 870° and 925°C.), and in room-temperature tensile tests.

The results showed that in all cases rare-earth additions increased rupture strength at high temperatures: the effect was more pronounced at 1500°F. (815°C.) than at 1600° or 1700°F. (870° or 925°C.).

Ductility, as measured in the stress-rupture test, was generally improved by the rare-earth additions; the improvement was greatest at 1500°F. (815°C.). Forgeability was not improved by the rare-earth modification, which appeared to impair hot-workability.

Minimum creep rate was lowered by a sufficiently large addition of rare earth, but a smaller amount may have the reverse effect. Room-temperature tensile tests revealed little effect of the addition metals.

Relation between Static and Fatigue Properties in Nickel-Chromium-Cobalt-Iron Alloy

NAT. ADVISORY COMMITTEE FOR AERONAUTICS: 'Co-operative Investigation of Relationship between Static and Fatigue Properties of Wrought N-155 Alloy at Elevated Temperatures.' *N.A.C.A. Tech. Note* 3216, Apr., 1955; 92 pp.

The report covers one part of a comprehensive investigation which has been in progress for some years, to determine the properties of N-155 alloy, as one of the typical alloys potentially useful for various forms of high-temperature service. The analyses of the material used in the present tests are given on p. 161.

The general objective of the tests was to obtain data which would define load-carrying ability at high temperatures and in conditions in which creep and fatigue can occur simultaneously. In view of the known difficulty in interpreting results of various types of fatigue test, duplicate data were obtained

	C %	Si %	Mn %	Cr %	Ni %	Co %	Mo %	W %	Nb %	N %
Supplier's heat analysis ..	0·13	0·42	1·64	21·22	19·00	19·70	2·90	2·61	0·84	0·13
Check analysis made at University of Michigan ..	0·14	0·35	1·43	20·80	18·80	19·65	3·00	2·00	0·99	0·135

from several kinds of fatigue-testing machine. The eleven laboratories which co-operated in the tests included representative U.S. Government and other scientific organizations, and industrial laboratories in America and England.

Extensive data were obtained relating the properties of the wrought alloy under static, combined static and dynamic, and completely reversed dynamic stress conditions. Time periods for fracture ranged from 50 to 500 hours, at room temperature and at 1000°, 1200°, 1350° and 1500°F. (538°, 648°, 734° and 815°C.).

Correlation of the data so obtained led to the following conclusions:—

As the temperature was raised increasingly higher percentages of dynamic stress, superimposed on the steady loads for rupture in 50, 150 and 500 hours, were required to change rupture strength appreciably. At 1500°F. (815°C.) the dynamic stresses approached the completely reversed fatigue strength before a substantial reduction in fracture time occurred.

As the steady stress was reduced, to increase time-to-rupture, a given amount of superimposed dynamic stress had progressively less effect on time-to-rupture.

In completely reversed stress tests fatigue strengths were obtained (over the whole temperature range) which were of the order of 40–60 per cent. of the static tensile strength. As the temperature and the time period were increased the fatigue strengths increased relative to the static rupture strengths, to as much as twice the rupture strength for 500 hours at 1500°F. (815°C.).

From a limited amount of data, the indication is that under combined stresses up to 67 per cent. of the steady load at 1350° and 1500°F. (734° and 815°C.) the fatigue stress did not appreciably alter the creep characteristic through the second stage of creep. Apparently, for this material, and under the test conditions used, superimposed fatigue stresses exerted their major influence during the third stage of creep.

Properties evaluated on the basis of number of cycles to failure differed from those evaluated on a time basis only when the properties were time-dependent. Thus, two fatigue machines operating at different cyclic speeds gave differing values on a cyclic basis when a fatigue limit was not attained. This feature was particularly clear in combined stress tests at 1350° and 1500°F. (734° and 815°C.).

Increasing amounts of fatigue loading progressively reduced elongation in the rupture tests. In completely reversed stress tests very low values were found.

Bending tests gave slightly higher fatigue strengths than completely reversed axial-stress tests. The difference decreased with rising temperature of test, and at 1500°F. (815°C.) the two types of test gave comparable results. Variation in cyclic speed appeared to have little effect. In axial tests the graph did not show the 'knee' typical of S-N curves, and with rise in temperature the knee tended, in all tests, to disappear.

The influence of surface finish became less with rise in temperature of test: variation in residual stress is considered to have been the main variable. At relatively low temperatures polished specimens gave higher strengths than ground specimens.

The report also contains some data on dynamic stress-strain properties, damping characteristics and the influence of notches in rotating cantilever beam tests.

Influence of Vanadium Pentoxide on Scaling of High-Temperature Alloys

W. BETTERIDGE, K. SACHS and H. LEWIS: 'The Influence of Vanadium Pentoxide on the High-Temperature Scaling of Heat-Resisting Alloys.'
Jnl. Inst. Petroleum, 1955, vol. 41, May, pp. 170–80.

The relevant earlier literature is discussed in relation to the contribution which it has made to elucidation of the nature of the attack suffered by metallic materials in contact with vanadium pentoxide, the conditions in which such attack occurs, and means for combatting it.

Work by earlier investigators has established that all alloys yet tested are corroded to some extent by vanadium pentoxide at temperatures above about 600°C. Constructors of equipment in which residual oils are burned are therefore faced with the problem of selecting, from materials which are suitable in other respects (e.g., strength under operating conditions, costs, etc.), those which show best resistance to corrosive attack. The work described in the present paper was undertaken with the object of providing information which would help to solve this problem. The research was on two main lines:

(1) determination of the rate of corrosive attack, under various conditions, on selected materials;
(2) determination of the effect of corrosion on mechanical properties.

The materials studied were chiefly nickel-chromium-base heat-resisting alloys of various types: a few specimens of austenitic stainless steels, one cobalt-base alloy, and pure nickel were also included. For details see table on page 162.

Nominal Compositions of Alloys

Alloy No.	C %	Si %	Cr %	Ni %	Co %	Fe %	Mo %	Ti %	Al %	Other Elements %
1	0·1	0·6	18	8	—	Bal.	—	—	—	—
2	0·1	0·6	18	8	—	Bal.	3	—	—	—
3	0·1	0·6	25	20	—	Bal.	—	—	—	—
4	0·12	0·5	18	12	—	Bal.	—	—	—	1 Nb
5	0·4	1·0	13	13	10	Bal.	2	—	—	2½ W, 2 Nb
6	0·27	0·5	19	10	Bal.	15	2	—	—	3 V, 1 Nb
7	0·1	0·5	20	Bal.	—	—	—	0·3	—	—
8	0·05	0·5	20	Bal.	—	—	—	2·3	1·2	—
9	0·05	0·5	20	Bal.	20	—	—	2·3	1·2	—
10	0·1	0·5	18	37	—	Bal.	—	—	—	—
11	0·1	2·0	18	37	—	Bal.	—	—	—	—
12	0·05	0·5	20	Bal.	—	—	—	—	3·5	—
13	0·05	0·5	14	Bal.	—	6	—	—	—	—
14	—	10	—	Bal.	—	—	—	—	—	3 Cu
15	—	5	15	Bal.	—	—	—	—	—	—
16	—	10	14	Bal.	—	—	—	—	—	—
17	—	15	15	Bal.	—	—	—	—	—	—
18	0·03	0·02	—	Bal.	—	0·2	—	—	—	—

In the first series of tests a study was made of the effect of vanadium pentoxide, and of mixtures of this oxide with sodium sulphate or calcium sulphate, on the resistance of 1-in. square sheet, strip, or cast plate samples to scaling when heated at 850°C., for 100 or 250 hours. (Control specimens were tested in air, to provide the necessary correction factor.)

In a further series of tests 10 mg. of vanadium pentoxide were supplied to the specimens daily. In view of the markedly beneficial influence of silicon, noted in the earlier tests, cast nickel-chromium-silicon alloys and nickel-silicon-copper alloys were included in the second series. The duration of these tests was 284 hours.

Details are given of the weight loss for each of the materials exposed under both conditions.

In order to assess the effects of ash corrosion on the stress-rupture properties of the materials, a modified form of test procedure had to be developed. Full particulars are given of three methods tried for application of the contaminants to the test pieces, and reasons for selection of one of these are discussed. The most satisfactory results were obtained by application, to the surface of the test bar, of a stiff-paste aqueous powder suspension of the contaminant(s).

Data on stress-rupture tests are considered in relation to loss-in-weight values for the respective materials: the mechanical tests were made at 750°C. and some confirmatory determinations were carried out at 870°C. Detailed microscopic examination was also made of the broken test bars, of samples used in the scaling tests, and of specimens which had been exposed in other conditions to vanadium pentoxide, with or without intensifying contaminants. Typical photomicrographs are shown.

The authors evaluate their results from two points of view:—

(1) the contribution which they make to closer understanding of the mechanisms by which the presence of an ash accelerates the rate of corrosion of alloys, and

(2) assessment of the effect of such corrosion on the serviceability of an alloy for high-temperature service.

With regard to (1), it is concluded that the protective oxide layers normally present on the surface of an alloy are removed by solution in the vanadium pentoxide, with the result that oxidation-resistance is reduced to a level substantially representative of that of the base metal in its initial state, before the protective oxide film forms. (It is not yet evident whether the vanadium pentoxide itself or oxygen in the atmosphere is the agent reacting with the alloy.) In the chromium-containing nickel- and

iron-base alloys it appears that the solution, at high temperatures, of the protective chromium oxide by the liquid vanadium pentoxide is the primary factor leading to accelerated corrosion. As oxidation proceeds and chromium is preferentially removed from the alloy the proportion of chromium to base metal in the alloy is progressively reduced, and the nature of the base-metal oxide becomes of increasing importance. Tests on pure nickel showed that the oxidation rate of this metal is not increased by the presence of vanadium pentoxide, indicating that nickel oxide is not fluxed by vanadium pentoxide at 850°C. and is therefore a valuable constituent in the scale of alloys which are required to resist this type of attack. Confirming this assumption, the laboratory tests recorded demonstrate that nickel-base alloys are much superior to iron-base alloys in resisting the accelerating action of pure vanadium pentoxide on scaling. Service conditions are, however, more complex, and in this connexion the presence of sulphur is significant. It has been found that sulphur attack is more likely to result from gaseous compounds in the atmosphere than from alkali sulphates present in the ash, although it is demonstrated that mixtures of vanadium pentoxide and sodium sulphate are more damaging than vanadium pentoxide alone. Here also, however, the nickel-base alloys are more resistant to attack than are the iron-base types.

It is suggested that on iron-rich alloys vanadium-pentoxide contamination produces an effect similar to that which has been called 'catastrophic oxidation', i.e., rapid bulk oxidation of the alloy, resulting in formation of voluminous spongy oxide and a sharply defined, relatively smooth scale-metal interface. In nickel-rich alloys, on the other hand, oxide penetrates into the metal, preferentially along the grain boundaries, and thus reduces the stress-carrying capacity of the alloy, without abnormally severe oxidation as judged by weight changes. It is believed that intergranular penetration is not observed in iron-rich alloys because the rate of advance of the bulk oxide is faster than the rate of intergranular attack.

The stress-rupture tests at 870°C. confirmed the results of the tests at 750°C. In the presence of vanadium pentoxide the austenitic steel suffered accelerated oxidation and showed an extremely severe reduction in life: the nickel-base alloys showed intergranular penetration, leading to rather scattered stress-rupture lives, but, in the relatively short-time tests made, the drop in life was very much less than that for the steel. The behaviour of the cobalt-base alloy was intermediate between that of the steel and that of the nickel-base alloys.

Oxidation-Resistance of Nickel-Alloy Cast Irons

See abstract on p. 159.

Thermal-Shock Resistance of Cast Irons

See abstract on p. 158.

Nimonic Stator Blading in Gas Turbine Running on Residual Fuel

'Gas Turbine Running on Residual Fuel.' *Engineer*, 1955, vol. 199, June 24, p. 884.

Notes on three-years' experimental work by Ruston and Hornsby, Ltd., carried out in conjunction with Esso Development Company, Ltd.

Following initial tests made to determine the effect of gas temperature (620°–770°C.) and the benefits obtainable from addition of various inhibitors to the oil, a 1000-hour test was made, under the following conditions:—

The fuel contained sulphur 3·5, vanadium 50, sodium 25-62, per cent., and 300 total ash expressed as parts per million. A magnesium additive was used and the test consisted of ten 100-hour runs. By means of equipment built into the turbines and fed with mains water, the turbine blading was water-washed to remove the small amount of deposit on the blades at the end of each 100-hour run. (About 90 per cent. of the deposit on the first row of stator blades could be removed in this way.) No stripping of the turbine was necessary for the washing and no other cleaning was required during the 1000-hour test.

The first five 100-hour tests were made at a mean gas temperature of 700°C., and on examination after the 500 hours' running it was found that the Nimonic 80 alloy stator blades were free from serious corrosion and in a condition satisfactory for further service. In the second 500-hour series the effect of gas temperatures between 650° and 750°C. was investigated, also the influence of concentration of the magnesium additive. A photograph illustrating the condition of the blading after water-washing at the conclusion of the 1000-hour test indicates no serious loss of metal.

Descaling and Cleaning of Stainless Steel

AMER. SOC. TESTING MATERIALS: 'Tentative Recommended Practice for Descaling and Cleaning Stainless Steel Surfaces.' *A.S.T.M. Designation* A 380-54T. 1954 *Supplement to Book of A.S.T.M. Standards, Part* 1, *Ferrous Metals*, pp. 453-9.

This schedule 'is intended as an aid to fabricators and engineers who, although familiar with ordinary cleaning practices, are confronted with new problems inherent in the descaling and cleaning of stainless-steel surfaces.' It covers procedures which have been found satisfactory for producing stainless-steel wrought, cast and fabricated surfaces free of metallic iron, oxide scale, and other foreign substances. Degreasing and stripping, blast cleaning, and pickling are covered in detail, and attention is given to cleaning problems arising in fabricated equipment (including welded assemblies), and to final cleaning of chemical-plant installations.

In connexion with inspection, particulars are given of methods which may be used for detection of traces of metallic iron and iron oxide possibly remaining on the surface after cleaning.

Electropolishing of Stainless Steels

'Contract Electropolishing. Plant and Process employed by a Trade Finisher.' *Electroplating*, 1955, vol 8, June, pp. 220–2, 227.

This article describes the plant and process used by Brightside Electropolishing Company, Ltd., which is working in association with Modern Electrolytic Patents and Processes, Ltd. The processes used are those developed in the U.S.A. by Battelle Memorial Institute and by the Jacquet/Hispano Suiza organization in France. The polishing solution is based on a phosphoric-sulphuric acid mixture.

Much interest in this mode of finishing is already evident in the metal and metal-fabricating trades. The work of the Brightside plant is at present confined to electropolishing of alloy steels (principally 18–8 chromium-nickel steel and stainless iron), but a programme of extension provides for plant to treat other materials.

Resistance of Nickel-containing Materials to Liquid Sodium

E. G. BRUSH: 'Construction Materials for Liquid Sodium Systems.' *Corrosion*, 1955, vol. 11, July, pp. 299t–303t.

The use of sodium as a heat-transfer agent in nuclear-power plants has introduced a new aspect of corrosion investigation, and much research is in hand to determine the most suitable materials for the construction of high-temperature irradiated heat-transfer systems which are cooled by liquid metal. In addition to normal effects occurring during aqueous corrosion, in the study of the reaction of liquid metals with metallic materials it is necessary to take account of other factors which play an important part in determining the suitability of specific materials for service use. In connexion with the problem of attack by liquid sodium, the author considers three special aspects which complicate the choice: mass transfer, preferential attack, and diffusion bonding. The nature of the attack is discussed and also the effects of contaminants in sodium, with particular reference to oxygen.

A summary is then made of conclusions drawn from a series of laboratory and pilot-plant tests carried out on a range of ferrous and non-ferrous materials. The main points are given below:—

Carbon and Low-Alloy Steels tend to decarburize, are liable to diffusion welding at temperatures in the region of 850°F. (455°C.), and are very sensitive to attack by sodium oxide.

Heat- and Corrosion-Resisting Materials. Steels of the 18–8 and higher-alloy chromium-nickel types may be regarded as immune from susceptibility to mass transfer up to 1000°F. (540°C.), they are not seriously attacked by sodium oxide up to 0·1 per cent. by weight of oxygen, they suffer no preferential attack, even when in the sensitized condition, and they are free from diffusion-bonding effects. Nickel and nickel-base alloys have not yet been studied so thoroughly as the austenitic steels, particularly with regard to their diffusion-bonding characteristics. Up to 1000°F. (540°C.) they show no tendency to mass transfer, but they are somewhat more susceptible than the chromium-nickel steels to sodium-oxide attack, which, at temperatures above 1300°F. (705°C.) becomes severe. Tests now in progress indicate that the austenitic steels are likely to be satisfactorily immune from mass-transfer effects up to 1500°F. (815°C.).

The 12 *per cent. chromium steels* may in many cases be substituted for austenitic steels for sodium service up to 1000°F. (540°C.). They are somewhat more sensitive than the chromium-nickel steels to sodium attack, but the difference is not significant in the range of oxygen contamination tolerable in the sodium.

Copper and Copper-base Alloys. Severe preferential attack limits the use of most of the common copper alloys in sodium systems.

Aluminium and Aluminium Alloys, and Magnesium. Mass-transfer of these materials, to stainless steel, precludes their use as gaskets.

Hard-Facing Materials. Since most of the hard-facing materials contain high percentages of chromium, their corrosion-resistance is broadly similar to that of the high-chromium steels. Caution must be exercized with regard to facing alloys containing silicon and/or boron, the effects of which are not yet fully established.

Nickel-Molybdenum-Chromium-Iron Alloys have not yet been fully studied, but it is known that resistance to corrosion under static conditions is good.

Cobalt-base alloys have good resistance to sodium, but their use in atomic power plant is limited by the nuclear disadvantages of cobalt.

Cermets, in particular cemented carbides with nickel, cobalt or molybdenum binders, show satisfactory resistance to corrosion by sodium at temperatures up to 1000°F. (540°C.), and it is believed that they may be useful also at higher temperatures.

Stainless Steel in Chemical Plant and Equipment

H. J. WILSON: 'Stainless Steel in the Chemical Industry.' *Manufacturing Chemist*, 1955, vol. 26, June, pp. 247–52.

This is a general discussion of the characteristics of stainless steels, and of their suitability for use in the chemical-engineering industries. The resistance of austenitic chromium-nickel to some common chemicals is considered. Some typical uses of various grades of stainless steel are described and illustrated, based on experience, over a prolonged period, in the plant of Monsanto Chemicals, Ltd., where a wide range of fine and heavy chemicals of high purity is produced. Some problems of design, fabrication, maintenance and use are discussed, with specific reference to various types of chemical vessel, piping, and other components. The economic advantage of stainless-clad steel for some applications is emphasized.

Cast Nickel-containing Alloys in Pickling Equipment

'Corrosion-Resistant Alloys Play Key Part in Pickling.' *Iron Age*, 1955, vol. 176, July 7, pp. 94–6.

The article gives details of two case histories,

selected from data obtained during a survey made by the Alloy Casting Institute, with the object of obtaining information on service behaviour of corrosion- and heat-resisting materials.

The first report relates to a typical brass-pickling installation (in the works of Scovill Manufacturing Company, Waterbury, Conn.), in which hand and batch processes formerly used have been replaced by a modern spray-pickling set-up. Each of the two mechanized pickling machines handles strip up to 30 in. wide, at speeds up to 600 f.p.m. It is claimed that the installation of these machines permits four men to pickle, in three hours, a quantity of strip which formerly had to be handled by thirty-two men and required two working shifts.

The cycle of operations is as follows: (1) warm sulphuric-acid power-spray pickle: (2) warm bichromate power spray: (3) cold fresh-water spray rinse, to sewers: (4) warm sulphuric-acid power-spray pickle: (5) recirculated power-spray cold-water rinse, combined with fresh-water rinse: (6) recirculated power-spray soap rinse: (7) hot fresh-water spray-rinse, to sewers: (8) hot-air blast.

The pump bodies handling the pickling solutions are made from CN-7M* alloy, which has high resistance to attack by the various concentrations of hot sulphuric acid used: CF-8M* alloy, used in flanges, valves, etc., provides specially good resistance to pitting corrosion frequently caused by acid salts. For accessory equipment and components not in direct contact with pickling acids, CF-8* alloy is found satisfactory. The judicious use of the three types of material has resulted in minimizing maintenance, lengthening life, and ensuring satisfactory service. The plant incorporates a continuous process which results in a uniformly clean surface on the pickled strip, without the over-pickling or localized etching which occurs when strip is stopped for stitching.

The second report comes from a plant in which strip of silicon steel and stainless steels is handled. In the process used for silicon steel the solution is a 10 per cent. sulphuric acid, at 180°F. (88°C.), prepared in the plant. Concentrated sulphuric acid is unloaded from tank cars and delivered to storage, whence it flows by gravity into the pickle tanks, for dilution to the required concentration. Spent acid is pumped into a gravity sewer leading into a collecting tank. The pumps handling the acid at every stage are made from CN-7M* alloy. For pickling stainless steel the concentrated sulphuric acid from the storage tanks is mixed in suitable concentration to form a solution containing also about 1 per cent. of hydrofluoric and 3-4 per cent. of nitric acid, which is used at 150°F. (65°C.). In these conditions also equipment of CN-7M* alloy is reported to give excellent service. The same material has proved satisfactory for the pumps and other parts handling the acids and milk of lime in the neutralizing plant in which the spent solutions are treated before disposal.

Designation of Alloy	C % max.	Si % max.	Mn % max.	S % max.	P % max.	Cr %	Ni %	Other Elements
CF-8	0·08	2·00	1·50	0·04	0·04	18–21	8–11	
CF-8M	0·08	1·50	1·50	0·04	0·04	18–21	9–12	Mo 2·0–3·0
CN-7M*	0·07	1·50	1·50	0·04	0·04	18–22	21–31	Mo 1·75–2·50 Cu 3·00 min.

* Durimet 20. Several other proprietary alloy compositions falling within the stated chromium and nickel ranges, and containing varying amounts of silicon, molybdenum and copper are also available.

For particulars of alloy compositions see table.

Pitting of Stainless Steel in Chloride Dye Solution: Preventive Methods

F. N. SPELLER: 'Severe Pitting of Stainless (18-8) Steel in Hot Chloride Dye Baths.' *Corrosion*, 1955, vol. 11, July, p. 303t.

This note gives an essentially practical account of service experience, the essential details of which are summarized below:—

Severe pitting had occurred in welded and cast chromium-nickel steel dyeing equipment. The process involved included a cycle of about ½ hour scouring with detergents at 180°F. (88°C.) followed by rinsing in fresh water before immersion in the hot fresh-water chloride dye bath. The actual dyeing operation lasted for about 40 minutes: during the last 20 minutes of this period 2 per cent. rock salt was added and the bath (at 180°F.: 88°C.) was agitated. A wetting reagent containing a small amount of Calgon was added to the bath.

Corrosive attack on the steel was highly localized, at welds or in exposed porous spots in castings. At these areas rusting was so severe that after two years it was necessary to clean the equipment thoroughly once a week in order to prevent discolouration of the fabrics handled. After four years many of the parts required replacement. The localized attack at fusion welds gave rise to stress-corrosion cracks and carbide precipitation, leading to disintegration of the steel. The primary cause of trouble was, however, fissures and cavities in badly made welds, which resulted in activation of the steel in the fissures, formation of passive-active cells, and some differential oxygen potential. In similar plant in which the welds were smooth (e.g., welds made by the inert-gas process) no local action occurred.

As an inhibitory measure, 500 p.p.m. of sodium nitrate or sodium chromate was added to the dye bath and to the scouring water before salting, and this modification eliminated about 80 per cent.

of the trouble. (Larger additions of inhibitor were impractical, since the dyes being used would have been affected). Successful results were obtained by adding a relatively small amount of inhibitor to the fresh-water dye bath during the first part of the dyeing cycle and to the solution used for the preceding scouring operation. It was evident that by this means a protective surface film was built up, conferring resistance to attack in the final dyeing period. Thorough washing of the equipment after dyeing of each batch is also necessary.

It is suggested by the writer that the persistent protective effect of inhibitors after removal from the inhibitor solution could with advantage be more frequently utilized in cyclic operation, e.g., in prevention of oil-tanker corrosion.

Corrosion-Resisting Alloys for Chlorine-Dioxide Pulp Bleaching

H. O. TEEPLE and R. L. ADAMS: 'A Corrosion Study in a Chlorine-Dioxide Pulp Bleaching Plant.' *TAPPI*, 1955, vol. 38, Jan., pp. 44–8.

During the past few years chlorine dioxide has been accepted as a commercially useful chemical for pulp bleaching: the main reason for this advance has been the development of practical means for generating chlorine dioxide at the plant. The present authors give a review of relevant literature.

The paper contains the results of a study in the chlorine-dioxide plant of Riegel Carolina Corporation at Acme, N.C. The aim of the investigation was to secure practical corrosion data for a wide range of metals and alloys, and the materials of construction exposed for test were therefore selected to be representative not only of those which might be expected to show good resistance to corrosion, but also of others suspected to be less suitable for this type of service.

The types of metallic material tested are shown below:—

Nickel
Inconel (nickel-chromium-iron alloy)
Monel (nickel-copper alloy containing 67 per cent. of nickel)
Hastelloy C (nickel-molybdenum-chromium alloy)
Chlorimet 3 (nickel-molybdenum-chromium alloy)
LaBour R-55 (complex nickel-base alloy containing chromium, molybdenum, copper, silicon, iron and tungsten)
Durimet 20 (nickel-chromium-iron alloy containing molybdenum and copper)
Austenitic 17–11 chromium-nickel steel containing molybdenum
Straight 19–10 chromium-nickel steel
16 per cent. chromium steel
Duriron (14·5 per cent. silicon-iron alloy)
Durichlor (14·5 per cent. silicon-iron alloy containing molybdenum)
Bronze (88–10–2 type)
Chemical lead
Tantalum

The materials were exposed in spool-type corrosion test fixtures and, with few exceptions, there were duplicate specimens on each holder. Conditions operative in the six sets of tests are shown below:—

(1) Top of chlorine-dioxide reaction tower, where the environment consisted of a solution of 60°Bé sulphuric acid, 32 per cent. sodium chlorate, methanol and chlorine-dioxide gas, at 135°F. (57°C.). There was some aeration, and the flow rate of the solution was 60 g.p.m. Duration of test was 351 hours.

(2) In chlorine-dioxide gas line to the absorber, where the environment consisted of chlorine-dioxide gas (8–10 per cent. by volume) with some condensed chlorine-dioxide solution. Flow rate 250 c.f.m., temperature 150°F. (66°C); duration of test 350 hours.

(3) In chlorine-dioxide solution receiver tank.

The concentration of chlorine dioxide was 4–5 g./L.: pH 2–3·5: temperature 36°F. (2°C.): duration of test 351 hours.

(4) In neutralizer tank.

The solution contained 45 per cent. sulphuric acid and 20 g./L. sodium chlorate. Temperature 155°F. (68°C.): flow rate 2–5 g.p.m.: duration of test 350 hours.

(5) In spent chlorine-dioxide gas, in the vent line from the bleach tower. Temperature 155°F. (68°C.): duration of test 338 hours.

(6) In the headbox of a pulp washer.

The kraft pulp stock was at a pH of 9·5–10; the temperature was 155°F. (68°C.), and there was moderate aeration. Stock flow rate 4,500 g.p.m.; duration of test 337 hours.

Results of the individual series of tests are given in the paper.

The data presented are considered to justify the following conclusions:—

'Tantalum shows excellent resistance to corrosion by any of the environments encountered.

'Durichlor shows good resistance to attack and appears to be limited only by its mechanical properties and forms available. Failures have occurred due to shattering resulting from vibration.

'Duriron, showing a high corrosion rate in test (2), seems to deserve no preference over Durichlor, and further has the same limitations of mechanical properties and forms available.

'Hastelloy C, cast, and Chlorimet 3, appear to have intermediate corrosion-resistance and, therefore, have limited application. It is worthy of note that the weight-loss corrosion rates for these two equivalent alloys were somewhat at variance. Hastelloy C has been used successfully for rotameter bobs and also for a connecting pipe between the chlorine-dioxide mixer and the retention leg of the bleach tower.

'LaBour R-55, with one exception, appears to be a good corrosion-resisting alloy, possessing quite favourable mechanical properties, and is probably worthy of consideration. The one exception was condensed chlorine-dioxide solution (test 2), where the corrosion rate was high.

'Chemical lead shows good to poor corrosion-resistance, and hence would have limited application.

Its mechanical properties also contribute to limiting its use.

'Molybdenum-containing chromium-nickel steel and Durimet 20, in general, cannot be depended upon to provide satisfactory service. In some instances the weight-loss corrosion rates are high, and in other instances, where the rates are low, these materials are subject to localized attack. Experience has shown that both are susceptible to intergranular failure.

'The straight 19-10 chromium-nickel and 16 per cent. chromium stainless steels, Monel, nickel, Inconel, and 88-10-2 cast bronze are not suitable for any applications in chlorine-dioxide bleach plant service, as has been shown by the data developed.'

Specification of Stainless Steel for Structural Use

E. W. HAMMER and R. E. PETERSEN: 'Design Specifications for Stainless Steel, Type 301.'
Amer. Iron and Steel Inst., Paper presented at Philadelphia Regional Technical Meeting, Oct. 6, 1954; 21 pp.

Chromium-nickel steel of the 17-7 per cent. type is becoming an increasingly important material to structural engineers. By cold rolling it is possible to obtain high mechanical properties, of the order of 125,000 p.s.i. (56 tons per sq. in.) in the quarter-hard condition and up to 185,000 p.s.i. (82·5 tons per sq. in.) for the full-hard material. In the latter condition the steel is employed, for example, in structural parts of aircraft, railway stock and other components in which a high strength : weight ratio is essential, and in which the toughness and corrosion-resistance characteristic of the steel are added advantages.

In order to draw up a design specification for the structural use of the 17-7 steel, an exhaustive series of tests is to be made, under the aegis of the American Iron and Steel Institute, in the laboratories of the Franklin Institute, Pennsylvania, Pa.

Much information relevant to the subject is contained in 'Strength of Stainless Steel Structural Members as a Function of Design', by M. WATTER and R. A. LINCOLN (published by *Allegheny Ludlum Steel Corporation*), and the first part of the investigation at the Franklin Institute is to comprise a checking of the formulae developed by these authors. The present paper gives results of verification tests on effect of forming on ultimate column load and related questions: later work will deal with formulae for determination of buckling and bending characteristics of cylinders, plates and panels, with torsional buckling of columns, and with methods for predicting column loads.

Monel-Clad Steel in Marine Protection

'Monel-Clad Steel for Protection of Marine Structures.' *Corrosion*, 1955, vol. 11, July, p. 78.

Monel-clad steel is being used for the tidal and spray-level sections of the tripod supporting the 'Texas towers', which will be located off the Atlantic coast to support aircraft-warning devices.

Rolling of Stainless-Steel Strip from Powder

'Foil from Stainless-Steel Powder.'
Metal Progress, 1955, vol. 67, June, pp. 190, 192, 194.
Digest of report entitled 'Rolling 18-8 Stainless-Steel Powder into Strip', by S. STORCHHEIM, J. NYLIN and B. SPRISSLER, published as *Report SEP*-161, by the *U.S. Atomic Energy Commission, Technical Information Service.*

The object of the work described was production of dense, strong and ductile foil from straight 18-8 chromium-nickel steel, and study of the effects of variation in powder, rolling technique, and feed, on the density and thickness of the strip produced. The influence of sintering conditions applied to green rolled strip, and of re-rolling after sintering, on mechanical properties, hardness, physical properties and corrosion-resistance, was also investigated.

The observations made show that strip of high density, showing good mechanical strength, satisfactory ductility and good corrosion-resistance, can be produced by this method.

Deposition of Hard-Facing Alloys in Powder Form

'Deposition of Hard-Facing Alloys in Powder Form.'
Engineering, 1955, vol. 179, June, pp. 773-4.

This note describes the T.L.B. process, developed by Dewrance and Company, Ltd. The outstanding feature of the equipment is a standard oxy-acetylene welding torch in which is incorporated a small metal-powder hopper, a powder-control valve and a powder nozzle. In operation, powdered metal is drawn from the hopper through the powder-control valve, into the gas stream which is passing through the torch, and flows, with the gas mixture, to the welding nozzle. The powder is heated as it travels through the flame, and by the time it reaches the base onto which it is to be deposited it is melted, thus ensuring a satisfactory bond. The metal powders used consist of alloys of various types, e.g., containing chromium, cobalt, nickel, molybdenum and iron; nickel, chromium, tungsten and cobalt, or nickel, silicon and boron. Alternatively, other hard-facing alloys such as Colmonoy, may be used.

The method has the advantage of increased speed (by comparison with other known methods of hard facing) and that it is automatic, thus obviating the need for skilled operators. Typical machines are described and illustrated in this note, and some of the applications of the process are indicated. Although developed primarily for facing of steam valves, it has many other potential uses, e.g., for pump parts, i.c. engine valves and other components in which hardness and resistance to erosion and corrosion are required.

Corrigendum

Nickel Bulletin, 1955, vol. 28. No. 9, p. 154.

Left-hand column, abstract relating to 'Resistance of Nickel-containing Materials to Oxygenated Water.'

In 10th. line of abstract, for 500°F. (120°C.) read 500°F. (260°C).

PATENTS

Nickel Electrodes for Accumulators

Sintered electrodes are produced by covering the support (e.g., nickel gauze) with nickel powder particles, compacting along the separation zones, loading with active electrode material, subjecting the composite to a charging and discharging cycle, and finally cutting along the separation zones, to produce individual electrode plates.

SONOTONE CORPN. (inventors, H. W. KOREN and G. BAUMSTARK). *U.S. Pat.* 2,708,211.

See also *U.S. Pat.* 2,708,212, in which electrodes made according to the method described in *U.S. Pat.* 2,708,211 are slightly modified in design.

Electrodes for alkaline accumulators consist of porous metal having a pore width less than 10μ, preferably less than 1μ. The thickness of the pore walls is 1-2μ. In a typical example nickel powder produced viâ the carbonyl (particle size 0·5 μ) is sintered at 700°C. and impregnated in vacuo with cadmium hydroxide.

BADISCHE ANILIN- UND SODA-FABRIK, A.G. *Brit. Pat.* 735,084.

Plastic/Metal Electrodes for Accumulators

Finely divided plastic particles are mixed with powder metal and the composite is pressed and sintered. An example relates to a composition of polystyrene 80 parts, very fine nickel particles 5 parts, and carbonyl-nickel flakes 15 parts, pressed at 120°C. The pores were impregnated with nickel hydroxide.

BADISCHE ANILIN- UND SODA-FABRIK, A.G. *French Pat.* 1,097,994.

Cathodes for Thermionic Tubes

A composite material suitable for use as a thermionically emissive cathode in an electron-discharge device is made by coating a heater wire with alundum, and passing the coated wire through a chamber containing nickel carbonyl while the wire is heated at 200°C. to ensure decomposition of the carbonyl and deposition of a nickel sheath on the wire. The coated wire is then heated to 950°C., cooled, and subsequently coated with the emissive material.

A. H. CHILDERS and D. GOLD, assignors to SYLVANIA ELECTRIC PRODUCTS, INC. *U.S. Pat.* 2,711,390.

Electrodeposition of Bright Nickel

Bright nickel deposits are obtained by adding to an aqueous acid solution of nickel sulphate and/or nickel chloride a bis-pyridinium compound (0·005-0·01 g./L.) in conjunction with a cyclic organic sulphur compound (0·2-15 g./L.) soluble in the acid nickel solution.

HARSHAW CHEMICAL CO. (inventor, W. J. SHENK). *Brit. Pat.* 732,562.

Deposition of Nickel by Immersion

For production of a nickel coating a light gas is dispersed in a bath containing nickel cations and hypophosphite anions. The gas (hydrogen, helium, methane, or neon) is chemically inert to the bath and has a molecular weight of less than 28.

GENERAL AMERICAN TRANSPORTATION CORPN. (inventors, D. E. MATHENY and P. TALMEY). *Belgian Pat.* 534,373.

Nickel-Cobalt Plating in Magnetic Recording Devices

In plating a base metal with nickel-cobalt alloy (for use in magnetic recording), recording characteristics are improved by adding to the plating solution 1-3 g. of toluene sulphonamide and 5-45 g. of boric acid, per litre of electrolyte. The basis plating bath preferably contains 10-75 g. of nickel chloride and 25-75 g. of cobalt chloride, per litre of solution. The method of plating by periodic reversal of current is claimed, and the patent also refers to a special grade of phosphor bronze suitable as the base metal member for the magnetic tape. The base-metal alloy is not, however, specifically claimed.

NATIONAL CASH REGISTER CO. *Brit. Pat.* 733,252.

Nickel-Phosphorus Coating of Electrodes

The electrode of a discharge tube is formed by coating the support with a eutectic or similar alloy of low vapour pressure. The preferred alloy contains nickel 89, phosphorus 11, per cent. After sealing the coated electrode is heated, to produce formation of a very smooth metallic layer.

ENGLISH ELECTRIC VALVE CO., LTD. (inventor, K. LENZ). *Brit. Pat.* 737,168.

Nickel-Cobalt Alloy for Magnetostrictive Elements

A magnetostrictive element used, for example, in echo-sounding devices, consists of a nickel-cobalt alloy containing cobalt 2-6, preferably 4, per cent. Improved efficiency is claimed, in particular a higher electro-mechanical coupling coefficient, at low and medium field strengths, than is obtainable in nickel.

MOND NICKEL CO., LTD. (inventors, K. G. HINTON and H. J. ROUND). *Brit. Pat.* 733,255.

Nickel-containing Thermocouple Alloys

The electropositive element of a thermocouple consists of an alloy containing chromium 10-25, niobium 0-2, iron 0-2, manganese 0-2, silicon 0·5-2, carbon up to 0·15, magnesium up to 0·2, alkaline and/or rare earths, aluminium and/or zirconium up to 0·4, per cent., balance nickel. The alloy of the negative element contains silicon 2-7, carbon up to 0·15, per cent., balance nickel. Preferred compositions are given.

BRITISH DRIVER-HARRIS CO., LTD. *Brit. Pat.* 733,535.

Nickel-Iron Alloys in Diamond Tools

The tool described comprises a diamond, a sintered matrix consisting of an alloy containing iron 64, nickel 34, per cent., and an alloy of diamond and the matrix material to act as a bond.

PRECISION DIAMOND TOOL CO. (inventor, J. TAEYAERTS). *U.S. Pat.* 2,716,404.

Boron Additions to Permanent-Magnet Alloys

Sintered age-hardenable permanent-magnet alloys containing nickel, iron and aluminium with additions of titanium, cobalt, copper, silicon and tantalum and/or niobium are improved by adding to the powder material, before sintering, boron 0·001–0·15, per cent. The addition is preferably made in the form of a powdered iron-boron alloy (containing boron 2–50 per cent.). The preferred composition lies within the range: nickel 12–18, aluminium 6–9, cobalt 20–35, copper 2–6, titanium 0–8, boron 0·001–0·15, per cent., balance iron.

DEUTSCHE EDELSTAHLWERKE, A.G. *Brit. Pat.* 734,597.

Precipitation-Hardening Nickel-Molybdenum Steel

Steel suitable for hot-press forging contains carbon 0·15–0·3, manganese 0·6–0·8, molybdenum 3·25–3·5, nickel 3–3·25, silicon 0·2–0·35, per cent., balance iron. The steel is normalized at 1840°–1860°F. (1005°–1015°C.) and tempered below 1100°F. (595°C.). Precipitation hardening occurs during use. Applications for which such steels may be used include dies and punches.

J. A. SUCCOP, assignor to HEPPENSTALL CO. *U.S. Pat.* 2,707,680.

Age-Hardening Nickel-Alloy Steel

Steel hardenable to at least Rockwell C 35 and having a V-notch Izod impact value of at least 10 ft.-lb. contains carbon 0·1–0·55, nickel 2·5–6, aluminium 0·8–3, molybdenum up to 2, manganese up to 2, chromium up to 2, silicon up to 1, per cent.; at least one of the elements vanadium 0·1–2, niobium 0·2–3, tantalum 0·2–6, and titanium 0·1–2, per cent., and up to 5 per cent. of other elements not impairing the hardness or toughness of the steel. Such steels are suitable for die blocks used in die casting.

P. PAYSON and W. G. JOHNSON, assignors to CRUCIBLE STEEL CO. OF AMERICA. *U.S. Pat.* 2,715,576.

Carbide/Metal Corrosion-Resisting Material

A sintered hard composition which is claimed to be corrosion-resistant consists of 42–72 per cent. of titanium carbide (devoid of free titanium, free carbon, oxides and nitrides), and 4–15 per cent. of a complex carbide solid solution containing niobium, tantalum, titanium and carbon. The binder consists of 20–50 per cent. of a nickel-molybdenum alloy containing 5–25 per cent. of molybdenum. The composite material is characterized by density of 5·6–6·8 g./cm.^{3}, hardness of Rockwell A above 83·5, and high resistance to oxidation at temperatures above 1800°F. (980°C.).

J. C. REDMOND and J. W. GRAHAM, assignors to KENNAMETAL, INC. *U.S. Pat.* 2,711,009.

Cobalt-Free or Low-Cobalt High-Temperature Alloys

The patent relates to alloys in which economy is effected by reduction or total elimination of cobalt, without impairment of creep-resistance. The following composition is cited:—chromium 4–12, titanium 3·5–8, aluminium 0·9–5 (titanium+aluminium 4·5–10), per cent., cobalt less than 10, zirconium up to 0·2, boron up to 0·01, carbon up to 0·25, iron up to 10, tungsten up to 5, molybdenum up to 5, manganese up to 1, silicon up to 1·5, niobium or tantalum up to 1, per cent., nickel balance. Optimum high-temperature properties are developed in alloys of this type by the following heat-treatment, which also forms part of the claim:— solution heating at 1050°–1250°C., re-heating as an intermediate step at 750°–1100°C., and precipitation-hardening at 650°–850°C. A typical alloy contains chromium 10·1, titanium 3·5, aluminium 1·86, cobalt 9·5, carbon 0·1, molybdenum 4·8, per cent., balance nickel.

MOND NICKEL CO., LTD. (inventors W. BETTERIDGE, A. W. FRANKLIN and R. A. SMITH). *Brit. Pat.* 737,178.

Complex Nickel-Chromium-Cobalt-base Alloys for Turbine Blading

Alloys for use at temperatures above 850°C., and in severe stress conditions, contain chromium 4–12, cobalt 10–55, titanium 0·5–8, aluminium 0·3–8, molybdenum 0–15, carbon 0–0·5, boron 0·001–0·01, zirconium 0·01–0·2, per cent., balance nickel. Iron up to 10, tungsten up to 5, manganese up to 1, silicon up to 1·5, and niobium and/or tantalum up to 1, per cent., may also be present. The proportions of titanium, aluminium, carbon and molybdenum, and the heat-treatment applied to the alloy, are such that under test at 9 tons per sq. in. and 870°C., a life to fracture of 100 hours or more is obtained. The preferred heat-treatment is heating at 1200°C. for 3 hours, rapid cooling to 800°C. (at which temperature the alloy is kept for 24 hours), and final ageing at 700°C. for 16 hours. The alloys are particularly suitable for use in gas-turbine blading.

MOND NICKEL CO., LTD. (inventors, W. BETTERIDGE, A. W. FRANKLIN and R. A. SMITH). *Brit. Pat.* 733,489.

Complex Cobalt-Nickel-Chromium-base Creep-Resisting Alloys

The following composition is cited for creep-resistant alloys:—carbon 1–2·96, silicon 0·35–1·07, manganese 0·54–1·06, nickel 7·8–12, cobalt 35–57, chromium 17·6–19, boron 0–0·5, per cent., with carbide-forming elements, e.g., molybdenum 2·9–4·5, vanadium 2·4–8·2, niobium 1·9–4·8, per cent. The total carbide-forming elements are present in the percentage 6·7–16. The balance of the alloy is iron.

G. T. HARRIS and H. C. CHILD, assignors to W. JESSOP AND SONS, LTD. *U.S. Pat.* 2,713,537.

A further group of creep-resistant alloys specified are of the following compositions: the preferred percentage of individual elements is shown in brackets: carbon up to 0·35, silicon 0·2–0·6, manganese 0·6–1, nickel 10–15 (12), chromium 18–20 (19), cobalt 42–46 (45), carbide-forming elements 5·4–7·5, per cent. With regard to the individual carbide-forming elements the following limits are proposed:—molybdenum 1·8–2·3 (2), niobium 1–1·4 (1·2), vanadium 2·6–3·1 (2·8). The balance of the alloy, preferably 16·6 per cent., is iron.

G. T. HARRIS and H. C. CHILD, assignors to W. JESSOP AND SONS, LTD. *U.S. Pat.* 2,713,538.

High-Temperature Components made by Infiltration of Porous Material

Skeleton bodies of titanium carbide mixed with chromium powder and/or chromium-carbide powder are embedded in aluminium oxide, with part of their surface exposed to receive the infiltrant, which is preferably nickel, cobalt, iron, or alloys of these elements with chromium, tungsten and molybdenum. Infiltration is effected in a controlled atmosphere and the temperature of treatment is above the melting point of the infiltrant.

SINTERCAST CORPN. OF AMERICA. *Brit. Pat.* 735,668.

Production of Insulating Oxide Layers on Electrical-Resistance Wire

Nickel-oxide layers characterized by mechanical strength and high electrical resistance are produced by heating copper-nickel alloys in a neutral gas to 600°C., admitting air or oxygen, and subsequently cooling in a neutral gas to below 300°C.

SOC. MÉPACO. *French Pat.* 1,097,818.

Corrosion- and Heat-resisting Nickel-Chromium-Copper-Molybdenum Steels

Corrosion- and heat-resisting steels contain chromium 3·6–20, nickel 5–20, copper and molybdenum at least 3·6 each, per cent. (copper+molybdenum 10–20 per cent.), carbon up to 1·7, per cent., balance iron (at least 50 per cent.). Preferred compositions are given below.

	Cr %	Ni %	Cu %	Mo %	Fe %
(*a*)	9·11	14·30	6·0	8·40	bal.
(*b*)	5·64	14·0	6·0	13·80	bal.
(*c*)	15·25	15·30	5·47	6·23	bal.
(*d*)	12·6	18·20	7·70	10·80	bal.

K. SPITZ. *Brit. Pat.* 737,553 (similar to *U.S. Pat.* 2,633,420).

Wear- and Corrosion-Resisting Nickel-Alloy Steel

A wear- and corrosion-resisting ferrous material contains carbon 0·5–4, chromium 11–30, nickel 0–15, silicon up to 1, manganese up to 1, vanadium 3–13, per cent., balance iron. It is specified that vanadium in excess of that soluble in the steel matrix shall be in ratio of 4·2 : 1 to the carbon in excess of that required to give the desired hardenability characteristics. Molybdenum 0–5, cobalt 0–3, per cent. and up to 0·5 per cent. each of titanium, niobium and tantalum may also be present.

D. J. GILES, assignor to LATROBE STEEL CO. *U.S. Pat.* 2,709,132.

Nickel-base Watch-Spring Alloys

Strip-form springs for watches and other purposes are made by homogenizing at high temperature, and quenching, a wire of an alloy having a cubic face-centred crystal lattice. The wire is cold-drawn to a cross-sectional reduction of 60–85 per cent., and finally rolled to give a total reduction of 90 per cent. The preferred alloy contains nickel 50–68, iron 5–25, chromium 12–25, molybdenum and/or tungsten 1–20, beryllium 0·1–2, titanium 0·1–3, manganese+silicon 1–4, per cent.

R. STRAUMANN. *Brit. Pat.* 733,510.

High-Expansion Nickel-Chromium-Manganese Steels

The high-expansion steel described is claimed to show mechanical properties superior to those of nickel-chromium-manganese steels previously used for this type of application. The percentage limits cited are shown below: the preferred ranges are in brackets: carbon 0·3–0·7 (0·4–0·6), nickel 5–20 (11–14), manganese 3–10 (4–7), chromium 9–12·5, one or more of the carbide-forming elements vanadium, tungsten, molybdenum, titanium, niobium and tantalum, in total not more than 0·4–1, per cent., iron balance. Silicon 0–1·2 and copper up to 3, per cent. may also be present. Heat-treatment comprises heating to 1000°–1250°C. soaking at 600°–775°C. for 1–20 hours, and oil-quenching to room temperature.

BRISTOL AEROPLANE CO., LTD. (inventor, P. H. FRITH). *Brit. Pat.* 737,002.

Brazing of Stainless and Heat-Resisting Materials

Materials containing high percentages of chromium, e.g., chromium-nickel stainless steels and heat-resisting alloys, are brazed with a compound containing palladium 60, copper 40, per cent., preferably one having a melting point of 1200°C.

BAKER AND CO., INC. *Brit. Pat.* 734,840.

Nickel-Chromium-Boron Brazing Alloy

Alloys for brazing corrosion- and oxidation-resistant high-temperature alloys, e.g., turbine blades, contain chromium 8–20, boron 2–5, nickel or cobalt 65–85, per cent. Brazing is effected at a temperature of at least 2000°F. (1095°C.) in a dry reducing atmosphere of hydrogen. Preferred composition: nickel 65–75, chromium 13–20, boron 2·75–4·75, iron 3–5, carbon 0·05–0·5, silicon 3·5–5·5, per cent.

W. M. BEAM and H. H. HANINK, assignors to CURTISS-WRIGHT CORPN. *U.S. Pat.* 2,714,760.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks.*

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